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Program and Information

SECOND INTERNATIONAL WORKSHOP

on

Discrete Time Domain Modelling of Electromagnetic Fields and Networks

Sponsored by:

The German IEEE MTT/AP Joint Chapter
The German IEEE CAS Chapter
The European Research Office of the U.S. Army
The Ferdinand-Braun-Institut für Höchstfrequenztechnik Berlin

In collaboration with the
MTT Technical Committee on Field Theory
(MTT-15)

October 28 and 29, 1993

Hotel Ambassador
Berlin, Germany

1. Program Co-Chairpersons

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2. Objectives

Due to advances in different areas of microwave- and millimeter-wave techniques, demand for efficient CAD tools has grown. This statement is today as true as it was at our last workshop held two years ago in Munich on this topic. The numerical analysis in time domain is attractive since it describes the evolution of physical quantities in a natural way. The two basic concepts, the modelling of fields and networks, are more closely related than it seems at first glance. In the TLM method, for example, the network model is the basis for modelling electromagnetic fields. Another example is the application of generalized S-matrix methods and diacoptics in field theory. The purpose of this conference is to stimulate synoptic considerations of field and network theory and to promote a lively exchange between researchers engaged in these fields.

3. Venue

The workshop will take place at the Hotel Ambassador Berlin, Bayreuther Str. 42/43, 10787 Berlin, Germany, Tel.: +49/30/21902-0, Fax: +49/30/21902-380.

4. Conference Secretary

For any questions or information about the workshop, please contact the Program Co-Chairpersons or

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5. Registration

Advance Registration may be done by the Registration Form enclosed in this Preliminary Program. On-site registration is also possible. The registration office at the Hotel Ambassador will be open at October 28, from 8:00 a.m. to 10:30 p.m..

Please note that late registration as well as on-site registration is subject to a late fee.

6. Projection Facilities

Projection equipment available will be a standard slide and an overhead projector.

7. Accommodation

Blocks of rooms have been reserved at the following hotels near or at the workshop site in Berlin at special workshop rates. Please make your reservations directly with the hotel. Refer to the Ferdinand-Braun-Institut für Höchstfrequenztechnik to obtain the special rate.

Hotel Ambassador	Bayreuther Str. 42/43
Tel.: +49/(0)30/21902-0	10787 Berlin
Fax : +49/(0)30/21902-380	205 DM single, 225 DM double
Hotel Westerland	Knesebeckstr. 10
Tel.: +49/(0)30/3121004	10623 Berlin
Fax : +49/(0)30/3136489	100 DM single, 155 DM double
Hotel Charlot	Giesebrechtstr. 17
Tel.: +49/(0)30/3234051	10629 Berlin
Fax : +49/(0)30/3240819	60/90/115 DM single, 170 DM double

Please note: **The rooms are only reserved until September 14, 1993.**

8. Transportation

Berlin is served by three airports: Berlin–Tegel, Berlin–Tempelhof and Berlin–Schönefeld. Berlin–Tegel is situated in the north–west of Berlin. You may take a taxi (about 30 DM) or the bus no. 109 directly to Berlin Zoologischer Garten (Berlin–Zoo) (35 min.). Berlin–Tempelhof located in the south–east of Berlin. You may choose a taxi (about 25 DM) or the underground (U-Bahn), U8 to Hallesches Tor and change to the U1 for going to Berlin–Zoo. If you arrive at Berlin–Schönefeld in the very south–east of Berlin, the most preferable way to get into the center is taking the S–Bahn directly to Berlin–Zoo (70 min.). A taxi will be about 60 DM. In general, public transportation in Berlin is the most preferable way of transportation within the city. During day–time, the underground and buses run every five or ten minutes.

If you are arriving by train, the trains will stop at Berlin–Zoo or Berlin–Hauptbahnhof from where you can take the S-Bahn directly to Berlin–Zoo. If you are arriving by car, leave the Autobahnring no. 10 at Autobahndreieck Drewitz to the Autobahn no. 115. At Autobahndreieck Funkturm, head towards north (look for the direction to the airport Berlin–Tegel) and get off the motorway at Kaiserdamm to arrive at Berlin–Zoo via Ernst–Reuter Platz. For your local orientation, we have enclosed two maps.

9. Program

This program consists of the invited talks and the non–invited contributions. Late contributions presented in session B2 will be accepted at the workshop.

Thursday, October 28, 1993:

8:00	Registration	

Session A1

8:30	Opening Session	
8:40	Time Domain Wave–Oriented Data Processing or: How to Extract Phenomenology from Observations	L. Felsen
9:25	Comparison of Different Field Theoretical Methods of Analysis of Distributed Microwave Circuit Elements	R. Sorrentino
10:10	-Break-	
10:30	Time Domain Electromagnetic Field Computation with Finite Difference Methods	T. Weiland
11:15	Finite Difference Time Domain Models for Coplanar Waveguide Discontinuities	V. Fouad Hanna
12:00	Enhanced FDTD Method for Active and Passive Microwave Structures	B. Houshmand, T. Itoh
12:45	-Break-	

Session A2

13:45	On the Field Theoretic Foundation of the Transmission Line Matrix Method	P. Russer, M. Krumpholz
14:30	TLM Modelling of Guiding and Radiating Microwave Structures	W.J.R. Hoefer
15:15	-Break-	
15:30	Time Domain Simulation of Non–Linear Networks Containing Distributed Interconnect Structures	M.I. Sobhy, E.A. Hosny
16:15	Modelling of Planar Microwave Structures in Frequency and Time Domain	R. Vahldieck

Social Event

19:00	Piano Recital: Diana Lawton Steinway–Haus, Hardenbergstr. 12
20:30	Berlin Evening Berlin Pavillon, Straße des 17.Juni 100

Friday, October 29, 1993:

Session B1

8:00	Dynamic Simulation of Semiconductor Devices	R. Stenzel, W. Klix
8:45	Signal-Processing Approach to Robust Time-Domain Modelling of Electromagnetic Fields	A. Fettweis
9:30	-Break-	
9:50	New Results in Transient Analysis of Crystal Oszillators	Ch. Schmidt-Kreusel, W. Mathis
10:10	Adaptive Detection and Tracking of Active Scatterers by Cascaded Notch Filters	M. Zouak, J. Saillard
10:30	Sub-mm Wave Circuit Characterization Using the Finite Difference Time Domain Method	N.I. Dib, L.P.B. Katehi
10:50	FDTD Modelling of Wirebond Interconnects	E. Pillai, C. Bornkessel, W. Wiesbeck
11:10	Distributed Computing for Transmission Line Matrix Method	P.P.M. So, W.J.R. Hoefer
11:30	TLM: Order of Accuracy Enhancement	D. de Cogan, A. Soulos, P. Enders
11:50	-Break-	

Session B2

13:00	Space and Time Discretization in Field Computation Using TLM	C. Christopoulos, J.L. Herring
13:20	Rigorous and Fast Computation of Modal Johns' Responses	M. Mongiardo, M. Righi, R. Sorrentino, W.J.R. Hoefer
13:40	Transmission-Line Matrix Modelling and Huygens' Principle or The Range of Applicability of TLM	P.Enders
14:00	Towards Better Understanding of the SCN TLM Method for Inhomogenous Problems	M. Celuch-Marcysiak
14:20	Generation of Lumped Element Models of Distributed Microwave Circuits	P. Russer, M. Righi, C. Eswarappa, W.J.R. Hoefer
14:40	Towards Exactly Modelling Open/Absorbing Boundaries	P.Enders, A.J. Wlodarczyk
15:00	-Break-	
15:20	Late Contributions	
16:00	Concluding Session: open forum, panel discussion, approximately finished by 17:00	

Recital Program

Berlin, Germany, October 1993

***Diana Lawton**, Piano*

I

W.A. Mozart — **Sonate d-dur, KV. 311**

Allegro con spirito
Andante con espressione
Rondo

II

C. Debussy — **L'Isle Joyeuse**

Intermission

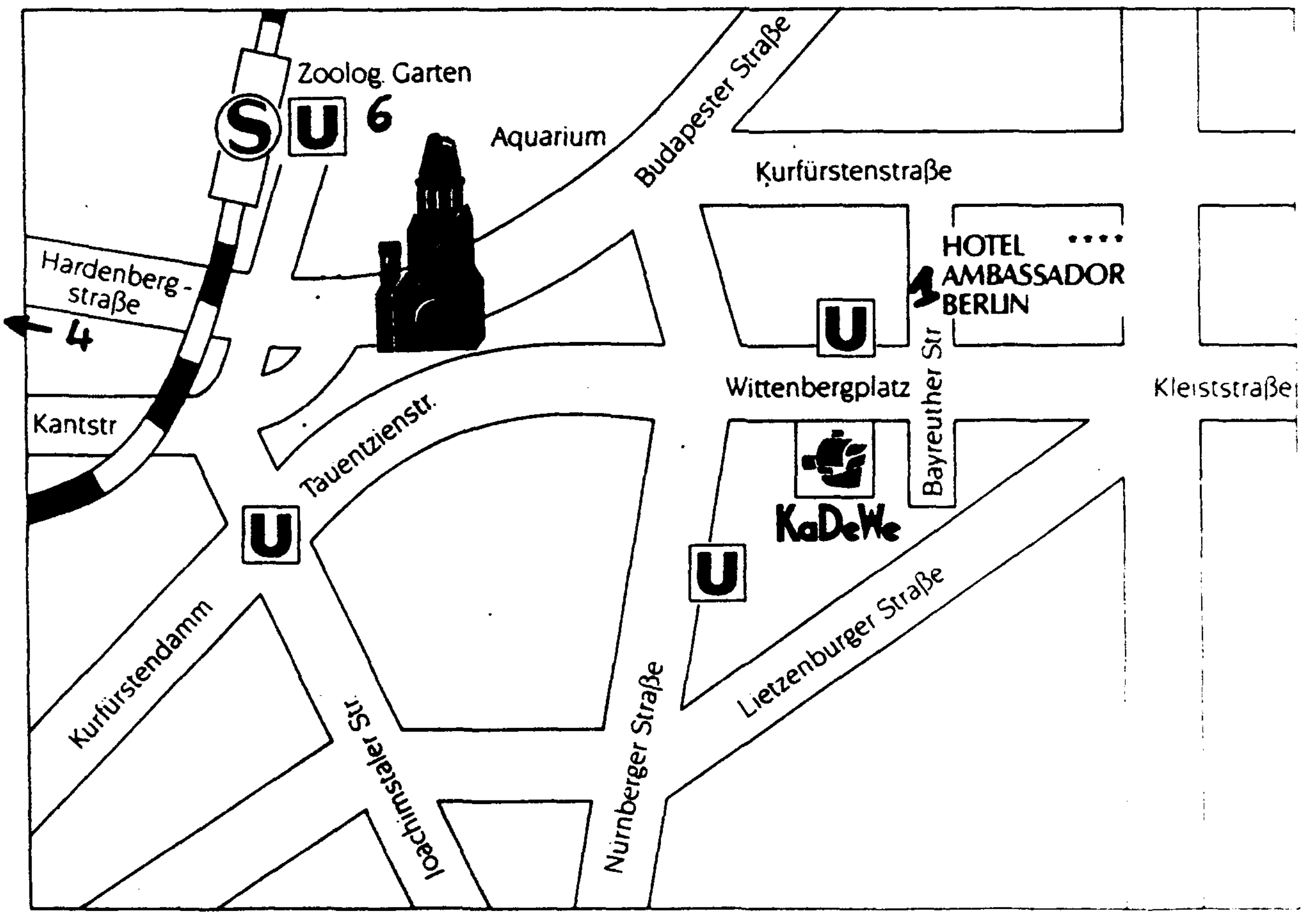
III

F. Chopin — **Sonate III h-moll, Op. 58**

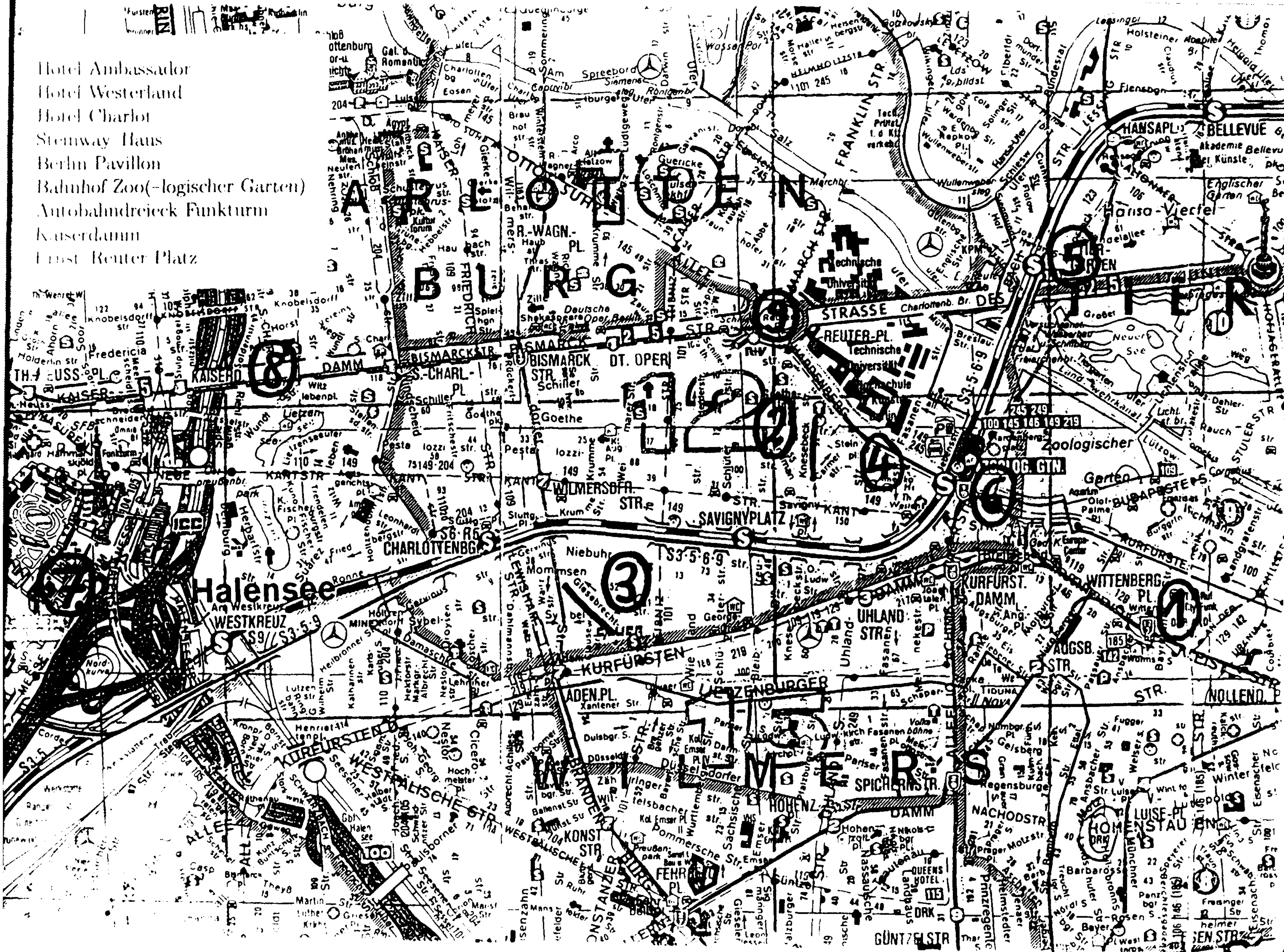
Allegro maestoso
Scherzo molto vivace
Largo
Finale presto, ma non tanto

WORKSHOP SITES AND HOTELS

1 Hotel Ambassador
2 Hotel Westerland
3 Hotel Charlot
4 Steinway–Haus
5 Berlin Pavillon
6 Bahnhof Zoo(–logischer Garten)
7 Autobahndreieck Funkturm
8 Kaiserdamm
9 Ernst–Reuter Platz



Hotel Ambassador
Hotel Westerland
Hotel Charlot
Steinway Haus
Berlin Pavillon
Bahnhof Zoo(-logischer Garten)
Autobahndreieck Funkturm
Kaiserdamm
Ernst Reuter Platz



REGISTRATION FORM

Name/IEEE number	....
	....
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Country	....
Phone	(.................)..
Fax	(.................)..

I wish to present a late contribution on the following topic: ....

Registration Fee

(includes proceedings, lunch and social event)

Please note:
Late registration as well as on–site registration is subject to a late fee.

IEEE members having paid by 1.10.1993	$200/320DM	$........
Non–members having paid by 1.10.1993	$250/400DM	$........
IEEE members paying after 1.10.1993	$240/385DM	$........
Non–members paying 1.10.1993	$300/480DM	$........
Extra tickets for the social event		
number	@ $45/75DM	$........
total enclosed		$........

Please make checks payable to the Ferdinand–Braun–Institut für Höchstfrequenztechnik Berlin. No credit cards accepted.

Remit this form to: Michael Krumpholz, Conference Secretary
Ferdinand–Braun–Institut für Höchstfrequenztechnik
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TIME DOMAIN WAVE–ORIENTED DATA PROCESSING

OR

HOW TO EXTRACT PHENOMENOLOGY FROM OBSERVATIONS

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Continually increasing capabilities for sophisticated measurement and numerical modelling are now available to generate data on signal transmission through, and scattering by, environments of substantial complexity. Intelligent extraction of information from the received signal for surveillance, identification, classification and other tasks is aided by linking features in data to physical features in the environment via the wave processes operative under the given conditions. To implement such wave–oriented data processing, it is suggestive to assemble a dictionary of individual scattering scenarios to determine the footprints established by each in the observed signal. Data from an actual physical or numerical experiment can then be projected onto the dictionary to see which of the reference signatures are contained in the data base. The method is based on local forward and backward tracking of wavefields in the phase space which combines both configurational (space–time) and spectral (wavenumber–frequency) constituents. The data processing is performed via windowed transforms and multiresolution techniques. Examples illustrate frequency and time domain phase space tracks produced by a variety of basic scattering scenarios, with numerical examples.

SIGNAL-PROCESSING APPROACH TO ROBUST TIME-DOMAIN MODELLING OF ELECTROMAGNETIC FIELDS

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In recent publications [1] – [6], a new method for integrating partial differential equations describing actual physical systems has been presented. This method is based on simulating the actual continuous–domain system by means of a discrete–domain system, and this in such a way that the following features hold:

1. Preservation of originally existing passivity and incremental passivity, and this in such a way that these properties become available in the multidimensional (MD) sense even though they existed originally only in the one–dimensional (1-D) sense (i.e. with respect to time). As a result, one can achieve not only full stability with respect to the discretization in space and time but also full stability, and, more generally, full robustness with respect to the computational errors that are due to rounding/truncation and overflow corrections and to extraneous sources.

2. Preservation of the massiv parallelism and the exclusively local nature of the interconnections, which is inherent to all physical systems with finite propagation speed. As a result, for any given fixed time instant to be considered, the computations can be carried out simultaneously, thus fully in parallel, in all the spatial sampling points, and the computations in any of these points require previously computed results only from the immediate neighbouring points.

3. Arbitrarily changing parameters as well as a arbitrary boundary shapes and conditions can be taken into account in a straightforward manner.

In order to achieve recursibility (computability), the simulation may not be based on the field variables appearing in the original partial differential equations. Instead, corresponding so called wave variables should be employed.

thus variables of the type occuring in relation with the scattering-matrix formalism. This way, the mechanism involved in the physical system becomes interpretable as an incidence-to-scattering (reflection, transmission) mechanism, i.e. a mechanism exhibiting a cause-to-effect (causality) relationship. The latter in turn gives rise to computational rules that exhibit the sequential nature needed for obtaining an algorithm.

It appears easiest to apply the method by first representing the system by means of a multidimensional electric circuit. From this, the desired algorithm can be derived by applying the standard procedures know from the theory of multidimensional wave digital filters [7], which has originally been developed within the context of digital signal processing. The approach is applicable without difficulty to systems described by Maxwell's equations.

References

[1] A. Fettweis, "New results in wave digital filtering", Proc. URSI Int. Symp. on Signals, Systems, and Electronics, pp. 17-23, Erlangen, Germany, Sept. 1989.

[2] A. Fettweis and G. Nitsche, "Numerical integration of partial differential equations by means of multidimensional wave digital filters", Proc. 1990 IEEE Int. Symp. Circuits and Systems, vol. 2, pp. 954-957, New Orleans, LA, May 1990.

[3] A. Fettweis and G. Nitsche, "Numerical integration of partial differential equations using principles of multidimensional wave digital filters", Journal of VLSI Signal Processing, vol. 3, pp. 7-24, 1991.

[4] A. Fettweis and G. Nitsche, "Transformation approach to numerically integrating PDE's by means of WDF principles", Multidimensional Systems and Signal Processing, vol. 2, pp. 127-159, May 1991.

[5] A. Fettweis and G. Nitsche, "Massively parallel algorithms for numerical integration of partial differential equations", in "Algorithms and Parallel VLSI Architectures", (edited by E.F. Deprettere and A.-J. van der Veen), vol. B: Proceedings, pp. 475-484, Elsevier Science Publishers, Amsterdam, 1991.

[6] A. Fettweis, "The role of passivity and losslessness in multidimensional digital signal processing – new challenges", Proc. 1991 IEEE Int. Symp. Circuits and Systems, vol. 1, pp. 112-115, Singapore, June 1991.

[7] A. Fettweis, "Wave digital filters: theory and practice", Proceeding IEEE, vol. 74, pp. 270-327, Feb. 1986.

FINITE DIFFERENCE TIME DOMAIN MODELS FOR COPLANAR WAVEGUIDE DISCONTINUITIES

Victor Fouad Hanna

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This paper assembles various models that were developped using the Finite Difference Time Domain (FDTD) Method to characterise coplanar waveguide (CPW) uniaxial discontinuities (step in width, gap, short–circuit, open circuit) and multimaxial ones (T junction, bends). Comparison of these models with those developped using other general purpose time domain methods like the TLM method or frequency domain ones like the finite element method will be presented whenever possible. Models for other possible CPW discontinuities used for monolithic applications like air bridges, connections between lines on different substrates and via holes for backed grounded CPW, will be given also. For CAD purposes, each of these discontinuities will be modelled between predefined reference planes either by an equivalent electric circuit or a scattering matrix.

TLM Modelling of Guiding and Radiating Microwave Structures

Wolfgang J. R. Hoefer

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This paper provides an overview of recent progress in modelling and simulation of electromagnetic structures with the TLM method. It is divided into three parts: New theoretical developments, computer implementation and validation, and design/optimisation.

New theoretical developments include generalized rectangular mesh algorithms for increased flexibility of discretization, new multi-modal Johns matrix techniques for high-quality absorbing boundary modelling in separable structures, and higher-order one-way equation models of absorbing boundaries for dispersive guiding structures as well as for open radiating structures, such as microstrip patch antennas. Methods for second-order accurate discretization of non-cartesian geometries are also described in the first part.

Computer implementation and validation of TLM algorithms are important aspects that determine the partical usefulness and reliability of the TLM method. The second part of this paper thus compares the serial and parallel programm structures of 2D and 3D TLM simulators, describes their performance on typical computer platforms, and conveys a flavour of the simulator–user interface. Solutions of several canonical problems demonstrate the accuracy of TLM results for time and frequency domain characteristics of microwave components, as well as for visualizing fields and circuit functions.

Design and optimisation are the ultimate engineering applications of a modelling technique. Two possible approaches are described in the third part. The first, more classical approach combines time domain field analysis with an optimization program. By using datapipe techniques, the TLM analysis can be performed on a powerful processor such as MASPAR or the Connection Machine, or the task can be divided among several workstations. The other approach makes use of time reversal to synthesize a structure geometry directly from its desired frequency response. This exciting new procedure is explained and demonstrated using a specific synthesis example.

The paper concludes with a look at possibilities and developments.

Enhanced FDTD Method for Active and Passive Microwave Structures

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It is well known that the FDTD (Finite Difference Time Domain) method is a powerful method for analyzing the electromagnetic wave behaviors in a complicated geometry. However, it is a memory intensive and time consuming operation. Recently, the author's group has invented and implemented several techniques to alleviate these deficiencies. Specifically, we have implemented the FDTD Diakoptics methods to use numerical Green's function to replace large computation volume with its impulse response. Hence, the memory requirement is drastically reduced. For acceleration of numerical speed, we have implemented a method based on the system identification technique. A reduction computation time of a factor of ten can readily been attained. In addition, for the first time in the electromagnetics community in the world, we can deal with a large volume containing active and nonlinear regions (or devices, plasma, etc.) by means of FDTD environment.

In this talk, fundamental concepts and efforts for their implementations are presented. Several examples are discussed. Since the methods are still in the development stage, some of the recent findings are also added at the time of presentation.

On the Field Theoretic Foundation of the Transmission Line Matrix Method

P. Russer[1,2] and M. Krumpholz[1]

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The TLM method, developed and first published in 1971 by Johns and Beurle has emerged as a powerful method for computer modelling of electromagnetic fields. In TLM the space is subdivided into cells. The electromagnetic field dynamics is modelled by wave pulses propagating between adjacent cells and being scattered within the cells. The main advantage of the TLM simulation resides in the capability to model circuits of arbitrary geometry, and to compute and to display the time evolution of the fields. The TLM method exhibits an excellent numerical stability and is also suitable for modelling of lossy, dispersive and nonlinear media.

Introducing the Hilbert space representation for the field state, the description of geometrical structures and the field evolution is performed algebraically. Field theoretical foundations of the two-dimensional TLM method and the three-dimensional TLM method with condensed node are given using the Method of Moments with sectional base functions. It is shown that the sampling of the tangential electric and magnetic field components in the cell boundary surfaces yields a correct bijective mapping between electromagnetic field components and TLM wave amplitudes.

The space discretization with regular meshs as well with nonuniform and curved meshs and the error introduced by the mesh discretization are discussed. For the calculation of the TLM and FDTD dispersion relations, we use a new generalized method. A critical comparison of two-dimensional and three-dimensional TLM with other finite difference time domain methods is given.

Time Domain Simulation of Non–Linear Networks Containing Distributed Interconnect Structures

M. I. Sobhy, E. A. Hosny

Electronic Engineering Department
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Canterbury, Kent, CT2 7NT, U.K.

Transmission properties of interconnects such as signal delay, reflection, attenuation, dispersion and crosstalk must be taken into consideration in the analysis and design procedures of high speed digital circuits and high frequency microwave systems. It is important to include the transmission line behaviour of interconnects between the system components, if the behaviour of the overall system is to be accurately simulated.

In general, the system can be divided into lumped, non–linear subnetworks and distributed interconnect structures. The distributed interconnects can be represented by different basic models of transmission lines, uncoupled lossless, coupled lossless, uncoupled lossy and coupled lossy transmission lines.

In this paper, different approaches are given to characterize the interconnects using time domain or frequency domain procedures. Each interconnect structure can be represented by a circuit block described by its terminal relations. In the simple case if the interconnect is modelled as a lossless and non–dispersive transmission line structure, the terminal relations can be represented by a set of difference equations. In all other cases the terminal relations can be derived by using calculated or measured scattering parameters of the interconnect structure in the time domain $s(t)$, which can be generated directly in the time domain or by transforming frequency domain data to the time domain.

If the interconnect is modelled as a lossy quasistatic transmission line, nodal time domain analysis can be applied to obtain directly $s(t)$. However, in the case of frequency dependent transmission line parameters and when

coupling between the transmission lines is not limited to adjacent lines, the time domain nodal approach does not apply. In the case of lossy and dispersive transmission line structures, $s(t)$ can be obtained directly by using time domain full wave anylysis (TLM and FDTD) or frequency domain analysis to obtain frequency domain scattering parameters which can be transformed to obtain $s(t)$.

Finally, we have now a set of lumped, non-linear subnetworks, all are modelled by their time domain terminal relations. A general procedure based on the state space approach has been developed to obtain the time domain analysis of whole network.

The transient responses of many examples have been obtained by using the proposed analysis procedure. These examples include different types of interconnect structures in high speed digital circuits and high frequency analogue circuits. The advantages of the proposed method are the high computational stability and efficient numerical accuracy.

Comparison of Different Field Theoretical Methods of Analysis of Distributed Microwave Circuit Elements

Roberto Sorrentino

Istituto di Electronica
University of Perugia
Perugia, Italy

Numerical methods for the analysis of microwave structures belong basically to two categories corresponding to the numerical formulation of Maxwell's equations in differential or integral form. Strictly numerical methods, on the one hand, are based on the discretization of Maxwell's equations, (e.g. Finite Element, Finite Difference (in frequency or time domain)) or on the implementation of Huygen's principle (Transmission Line Matrix (TLM) method). Thanks to their flexibility, they are well suited for problems with irregular geometries. On the other hand, methods requiring a degree of mathematical preprocessing, such as Spectral Domain Approach (SDA) and mode matching (MM), lead to very efficient computer codes, but are limited to problems with simple geometries.

To illustrate the above aspects, a comparison between the Finite Difference Time Domain and the Mode Matching methods as applied to the analysis of practial microwave structures will be presented in this paper. The methods are compared in terms of CPU, memory requirements, versatility, accuracy of the results, etc. A number of examples of components and discontinuities both in conventional as well as integrated technologies will be discussed.

DYNAMIC SIMULATION OF SEMICONDUCTOR DEVICES

Roland Stenzel[1], Wilfried Klix[2]

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Fachbereich Elektrotechnik
[2]Technische Universität Dresden
Institut für Grundlagen der Elektrotechnik/Elektronik

Development and optimization of novel semiconductor devices demand the use of two (2D)– and three (3D)–dimensional simulation methods.

At first a survey of the different model levels of device simulation (microscopic and macroscopic models) will be given. Subsequently the 2D–simulator SEMICO and the 3D–simulator SIMBA developed at the Dresden Polytechnic University of Technoloy and Economics and the Dresden University of Technology will be presented. In these programs drift–diffusion models are used and the semiconductor equations are solved with finite difference methods.
The paper contains a discussion of:

- basic semiconductor equations
- models for mobilities, recombination, generation, temperature dependence
- material parameters
- boundary conditions
- numerical methods
- spatial discretization
- time integration
- treatment of large linear systems of equations
- calculation of Y–parameters
- calculation of typical power gains and of small–signal equivalent circuit models

The different simulation possibilities are demonstrated in connection with novel III/V–heterojunction devices (HBT, HEMT, IPG).

Modelling of Planar Microwave Structures in Frequency– and Time–Domain

R. Vahldieck

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Dept. of Electrical and Computer Engineering, University of Victoria
Victoria, B.C., Canada V8W 3P6

Time– and frequency–domain techniques are complementary tools in the analysis and design of microwave and optical integrated circuits. While time–domain methods are very useful for wideband applications like transient problems as well as for nonlinear analysis, frequency–domain techniques are computationally more efficient for the majority of microwave design problems, which are of comparatively narrow band nature.

To address the different design problems within the framework of one analysis technique, the finite difference (FD) technique in the frequency–domain and the finite difference time–domain (TDFD) technique are available as complementary tools. For the time–domain transmission line matrix (TDTLM) method, no frequency–domain counterpart existed until recently when the TLM node was tested in the frequency–domain in conjunction with a novel S–parameter extraction technique. The resulting frequency–domain TLM (FDTLM) technique is a very powerful and flexible numerical modelling tool for frequency–domain design problems. Its computational efficiency and flexibility is better than most frequency–domain techniques known today. Since the space discretization is using the same transmission line nodes as in the TDTLM, the FDTLM represents a true frequency–domain counterpart to the time–domain TLM.

In this paper a general overview will be given about modelling microwave circuits in the time– and frequency–domain. New research results concerning the FDTLM will be presented and its relationship to the TDTLM will be discussed.

domain. This is a typical example where both frequency and time domain analysis are essential and only the combination yields the successful result.

Typical engineers may wonder why one applies time domain analysis to basically monochromatic field problems at all. The anwser is simple: it is much faster, needs less computer memory, is more general and typically more accurate. Speed up factors of over 200 have been reached for realistic problems in filter and wave guide design.

The small core space requirement makes time domain methods applicable on desktop computers using millions of cells, and six unknowns per cell - a dimension that has not yet been reached by frequency domain approaches. This enormous amount of mesh cells is absolutely necessary when complex structures or structures with spatial dimensions of many wavelengths are to be studied. Our personal record so far is a waveguide problem in which we used 72.000.000 unknowns.

We will present a number of conventional examples from electrical engineering and the forefront research in high power RF generation to demonstrate that time domain methods are 'better by design' and that there is no pure frequency domain method around that can reach the same generality and practicability.

Time Domain Electromagnetic Field Computation with Finite Difference Methods

T. Weiland

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The solution of Maxwell's equations in time domain has now been used for more than two decades and has had great success in many different applications. The main attraction of the time domain approach, originating in a paper of Yee, is its simplicity. It takes only marginal effort to write a computer code for solving a simple scattering problem compared with conventional frequency domain methods.

However, when applying the time domain approach in a general way to arbitrarily complex problems, many seemingly simple additional problems add up.

We present here a theoretical framework for solving Maxwell's equations in integral from, resulting in a set of matrix equations, each of which is the discrete analogon to one of the original Maxwell equations. This approach is called Finite Integration Theory and was first developed for frequency domain problems also about two decades ago. The key point in this formulation is that it can be applied to static, harmonic and time dependent fields, mainly because it is nothing but a computer-compatible re-formulation of Maxwell's equations in integral form.

When specialized to time domain fields, the method actually contains Yee's algorithm as a subset. Further additions include lossy materials and fields of moving charges, even including fully relativistic analysis.

For many practical problems the pure time domain algorithm is not sufficient. For instance a waveguide transition analysis requires the knowledge of the incoming and outgoing mode patterns for proper excitation in time